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Tung production

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CONTENTS

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Tung production

GEORGE F. POTTER, *principal physiologist, and* HARLEY L. CRANE, *principal horticulturist, Crops Research Division, Agricultural Research Service*

PRODUCTION IN THE UNITED STATES, IMPORTS AND USE

THE TUNG TREE produces one of the best quick-drying oils for industry. Planting in the United States is limited to a belt 75 to 100 miles wide, extending from eastern Texas to the Atlantic Ocean, including those portions of Louisiana, Mississippi, and Alabama nearest to the Gulf of Mexico, the northern third of Florida, and the southern third of Georgia. (See fig. 1.)

The tung tree is native to central and western China, where seedlings have been planted for thousands of years. Tung was introduced into the United States in 1905 by Consul General L. S. Wilcox, who sent seed to the State Department. This seed was turned over to the Section of Foreign Seed and Plant Introduction (now Section of Plant Exploration and Introduction) of the United States Department of Agriculture.

The first successful commercial orchard was planted in 1924 in Florida. The first mill for expressing oil was placed in operation near Gainesville, Fla., in 1928. A few large-scale plantings were made in the late 1920's and early 1930's, and extensive plantings were made in the late 1930's.

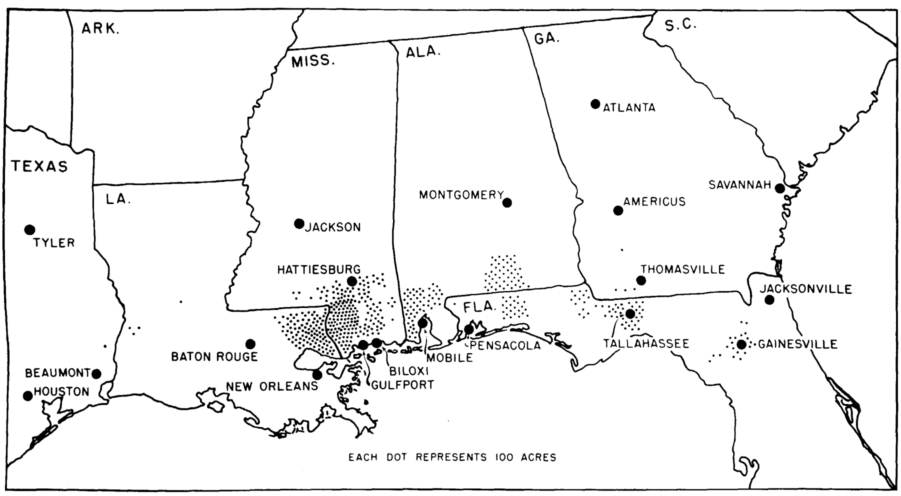

FIGURE 1.—The Tung Belt of the United States is about 100 miles wide and extends from eastern Texas along the Gulf of Mexico to the Atlantic Ocean. Dots on the map indicate 1950 acreages.

Production of tung fruit (nuts) increased rapidly from 1939 through 1952, a little more than 1,000 tons being produced in 1939, and 132,000 tons in 1952, yielding more than 42,000,000 pounds of oil. Although the price of oil has declined, planting of new high-yielding varieties continues on a moderate scale, and most of the orchards are not yet in full production.

Tung trees have been reported growing satisfactorily in certain localities north of the Tung Belt, but trees cannot be grown commercially in those areas. Warm winters, inadequate rainfall, and the high cost of land, irrigation, and labor practically exclude the Pacific coast and the Southwest as tung-producing areas.

The tung tree is very exacting in its climatic requirements and also in its soil requirements. It has been relatively free from insects and diseases, only a few having caused losses serious enough to justify control measures.

In the United States most tung is produced on large, specialized plantations, but tung production fits well into diversified farming. It requires relatively little labor during the time of year that most other crops need attention, and provides productive employment in winter.

A farmer already living on the land can start a tung orchard with a very small cash outlay. Machinery already on the farm will usually do for a small orchard. Large acreages require several kinds of modern farm implements. These can be acquired as the enterprise grows.

Production in the United States has been increasing steadily. Over the period 1950 to 1954, inclusive, during which losses from frost were larger than in any previous 5-year period, the average annual oil production was 23,500,000 pounds. In the two frost-free years, 1952 and 1953, average annual oil production was slightly more than 40,000,000 pounds, which is at least 80 percent of the present domestic requirements.

Tung oil imports into the United States began about 1870 but did not reach an appreciable volume until the early 1900's. Between 1912 and 1919, imports averaged a little more than 43,000,000 pounds a year. Between 1920 and 1937, imports increased steadily until more than 174,000,000 pounds were shipped to this country in 1937. Since then, imports have fluctuated widely due to the Sino-Japanese War, World War II, and an embargo on imports from Communist China. During the period 1951 to 1954, about 30,000,000 pounds of tung oil were imported annually, largely from Argentina.

Factory consumption closely paralleled imports during the period 1912 through 1937. Beginning in 1938, consumption declined because of the slump in imports. During World War II, imports practically ceased, but stocks were sufficient to keep consumption at a level of 10,109,000 pounds in 1944. Beginning in 1945, use of tung oil increased rapidly, and in 1948 the prewar consumption level of 130 million pounds was again reached. Subsequently the use of soya bean oil and tall oil increased, and that of other drying oils including tung oil decreased. Since 1952, about 50 million pounds of tung oil have been consumed annually.

Three principal users of tung oil are the paint and varnish, linoleum and oilcloth, and printing-ink industries. These consumers use the oil to produce rapid-drying paints and varnishes, aircraft finishes, moisture-proof coatings for cloth and other fibrous or porous materials, and inks. Tung oil products are used to coat containers for food, beverages, and medicines. Large quantities are used as insulation for wire and other metallic surfaces such as those in radio, radar,

telephone, and telegraph instruments. Tung oil is also used in the production of synthetic resins, artificial leather, felt-base floor coverings, wallboard, and paper products. In addition, it is used in lithographic printing; in the manufacture of certain types of gaskets, brake linings, lubricants, and greases; and in cleaning and polishing compounds.

Intensive research conducted in recent years enabled many manufacturers who formerly were consumers of tung oil to make satisfactory products from other materials. The market for tung oil was correspondingly weakened. Research may open up new markets by finding new uses for tung oil and the by-products of the milling industry.

THE TUNG TREE

Tung, botanically *Aleurites fordii*, is a member of the Spurge family and is the most valuable species of the genus. It is native to central and western China, where it is widely grown under primitive methods of culture. Tung yields most of the commercial "tung oil," although a related species, the mu-tree (*A. montana*), yields an oil so similar to that of tung that the two are perfectly compatible. In southern China, the mu-tree is the prevailing commercial species. In this country, the mu-tree could be grown only in central or southern Florida where the winters are very mild. Three other related species, the Japan wood-oil tree (*A. cordata*), the candlenut, or lumbang, tree (*A. moluccana*), and the the soft lumbang tree (*A. trisperma*) yield inferior oil. They cannot be grown commercially in the United States.

In early spring the tung tree is highly ornamental, blossoming with clusters of whitish, generally rose- but sometimes yellow-throated flowers. Broad, handsome, dark-green, heart-shaped leaves appear usually just after, but sometimes slightly before, the bloom. The shape of the leaves gave the tree its name, tung being a Chinese word for heart.

The flower clusters, which are borne at the ends of shoots produced the previous season, may consist wholly of staminate (male) flowers, or, in rare instances, of pistillate (female) flowers only. Usually, however, one or more pistillate flowers are surrounded by a number of staminate flowers. New shoot growth is made from growing points located within the terminal buds of the shoots.

The tree grows rapidly to a height of 40 feet or more and when mature has a spread approximately the same as the height.

Tung trees usually begin to bear fruit the third year from planting in the orchard; with good care, they should be in commercial production by the fourth or fifth year, and should attain maximum production by the tenth to twelfth year. Some of the first orchards planted in the United States are still bearing satisfactorily. The average life of the tung tree in this country should be at least 30 years.

Tung fruits are about the size of small apples (fig. 2). They are

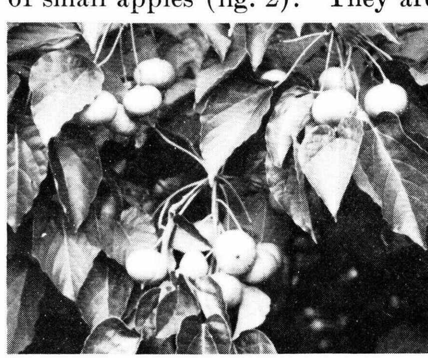

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FIGURE 2.—Portion of a tung tree showing the heart-shaped leaves and the fruits, which are about mature.

generally spheroid but may be shaped like a top, a tomato, or a pear. They mature and drop to the ground in late September to early November. At that time, they may contain as much as 60 percent moisture by weight. The fruits are dried to about 15 percent moisture before they are processed. An average fruit contains 4 or 5 seeds, but the number may be from 1 to 15. The seeds vary in size from $\frac{3}{4}$ to $1\frac{1}{4}$ inches long and from $\frac{1}{2}$ to 1 inch wide. Generally the greater the number of seeds per fruit, the smaller the size of the seeds. The seed is composed of a hard outer shell and a kernel. The oil is obtained from the kernels.

CLIMATE

Tung is even more exacting than pecans or cotton with respect to heat requirements. Production is best where both the days and nights are uniformly warm. Much variation in day and night temperatures reduces tree growth and fruit size.

The tung tree requires at least 45 inches of rainfall rather evenly distributed through the year. This large and constant water supply is needed because tung trees have large leaves and grow under hot summer temperatures on soils of low water-supplying capacity. Dormant tung trees require chilling during winter for 350 to 400 hours at temperatures of 45° F., or lower. If this cold requirement is not met, the trees generally start growth and flower late and irregularly, and tend to produce suckers from the main branches.

The cold resistance of the tung tree depends largely upon its vigor and its degree of dormancy when minimum temperatures occur. Vigorous but not succulent growth is the most cold-resistant. Thoroughly dormant, well-nourished trees have withstood temperatures down to 8° F. and even lower. Under the same conditions, a poorly nourished tree or an exceedingly succulent one might be partly killed back, if not entirely destroyed.

The rate at which the temperature falls, and the weather preceding the minimum temperature are also important factors. A gradual drop following a period of rather cool weather will cause much less injury than a rapid drop after a period of warm weather. Trees that have been stimulated to activity by unseasonably warm weather are extremely sensitive to cold and have been killed to the ground by temperatures of 23° to 28° F. occurring just after active growth had started in the spring.

SELECTING AND PREPARING LAND

Site Selection

Because tung trees start growth and blossom early in the spring (February or March), there is risk of cold injury. This risk is greatly reduced if orchards are planted on hilltops and slopes (fig. 3). On a still night, cold air will drain from the hilltops and settle in the bottom lands. "Frost pockets", which are depressions with no outlets through which cold air can drain to lower ground, should not be planted. A forest at the bottom of a slope may create a frost pocket by impeding the passage of cold air.

Good air drainage is of major importance in reducing losses from spring frosts. The wider the valley and the smaller the area draining into it, the lower the elevation may be for plantings.

Many growers combine the tung enterprise with beef production, and develop pastures on the lower slopes.

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FIGURE 3.—These tung trees, contour-planted on high, rolling land, will escape frost injury at times when crops are destroyed in orchards on lowlands or flat fields.

It is wise to select a site where previous tung plantings have led to the establishment of a mill at which the crop can be marketed and processed, or in an area where new plantings will justify the establishment of a mill. Distance to supplies of fertilizer and equipment should also be considered, as well as the availability of an adequate labor supply. Good roads to the site are desirable because the crop is generally hauled to market in winter when unimproved roads are likely to be at their worst.

The price of land must also be considered. Tung makes its best growth on virgin land. However, if virgin or cut-over land is not available, the prospective grower might purchase old, cleared farm land. Many successful orchards have been developed on "worn-out" farms. The soil must be satisfactory from the standpoint of drainage, depth, and texture; green-manure crops must be turned under; weeds must be controlled, and proper fertilizers used.

Soil Selection

A tung-growing enterprise is a long-term investment, and it is quite important that the proper soil be selected. That a soil is unsuited for tung production may not become apparent for several years after the trees are planted. A shallow, poorly drained soil, for example, may produce satisfactory tree growth for several years, especially if the seasons are favorable; but as the orchard comes to maturity, growth and production of the trees will be seriously reduced.

Tung trees require soils that are deep, well-drained, and aerated; that have a high moisture-holding capacity, and are easily penetrated by roots. **Should tung be planted on a soil that is unsuited in these physical characteristics, the error can never be corrected.** The soil should also contain an adequate nu-

trient level and have a satisfactory degree of soil acidity. However, it is possible to correct low fertility by adding fertilizers, and to correct excessive acidity by adding dolomitic lime.

A soil is made up of various layers (horizons), each of variable depth. The total depth of these horizons may be several feet, and widely different soils may have similar surface layers. In order to tell whether a soil is suitable for the production of a deep-rooted crop, such as tung, it is necessary to know the properties of the lower layers. Soil maps of certain areas and counties are available from most State agricultural experiment stations or from the Soil Conservation Service, U. S. Department of Agriculture, Washington, D. C.

Good drainage is one of the most important considerations in choosing a soil for growing tung trees. Many soils are not sufficiently well drained. Either the permanent water table is too high, or drainage is retarded by a hardpan or a heavy clay layer.

The best soils are those with subsoils that have enough clay to provide an adequate moisture and nutrient reservoir and yet have enough sand and silt to provide satisfactory internal drainage. A uniform, brightly colored subsoil indicates good drainage.

Subsoils that are white or light gray, or are streaked with dull-gray, brown, and yellow mottlings have poor drainage. Other soils may be much too sandy, thus being especially low in moisture, in fertilizer-storing capacity, and in fertility. It is possible to grow good tung trees on these sandy soils, but the cost of production is higher than on heavier, well-drained soils.

Soil Acidity

Soil acidity is usually measured in terms of pH. Soils with a pH of 7.0 are neutral, soils below 7.0 are acid, and those above are alkaline. A soil with a pH of 6.5 is considered slightly acid; one with a pH of 6.0, moderately acid; with a pH of 5.0, strongly acid; and with a pH of 4.0, extremely acid.

Most soils of the Tung Belt are slightly to strongly acid, ranging from pH 6.5 to 4.5, most of them having a pH of less than 6.0. Although the tung tree is tolerant of strongly acid soils, leguminous cover crops grow best on soils with a pH of 6.5 to 6.0 (slight to moderate acidity), growth decreasing moderately as the soils become alkaline, and rapidly as they become more acid than pH 6.0. Therefore, liming would be beneficial to most soils in the Tung Belt; the more acid the soil, the greater the amount of lime required.

Phosphorus is most readily available in slightly alkaline to slightly acid soils, and its availability decreases rapidly when the pH is lower than 6.5. Strongly acid and extremely acid soils supply almost no phosphorus.

Maximum availability of zinc, copper, and manganese to plants is found in soils that are strongly to very slightly acid. Because the availability of these elements begins to decrease when the pH is about 6.5, growers should avoid adding amounts of lime that will bring the soil to a higher pH.

Soil Types

Ruston sandy loam is one of the most desirable types of soil for tung trees. This soil occurs extensively throughout the Tung Belt except in peninsular Florida. The surface is a grayish-brown sandy loam, and the subsoil is a uniform brown, friable, sandy-clay loam.

Closely associated with Ruston in soil type and location and equally good for tung are the Orangeburg, Red Bay, and Norfolk sandy loams. The Orangeburg and Red Bay subsoils are red, friable, sandy-clay

loams and the Norfolk subsoil is a yellow, friable, sandy-clay loam. Other excellent but less extensive soils for tung are Greenville, Marlboro, Magnolia, Faceville, Carnegie, and Tifton.

In peninsular Florida, the Gainesville and Arredondo loamy sands and sandy loams are well suited to tung growing.

Extensive plantings of tung have been made in Mississippi and Louisiana on Ora, Dulac, Savannah, and Franklinton — very fine sandy loams. These soils are satisfactory for tung production, although they are somewhat less productive than those mentioned above. The Ora and Dulac soils have relatively heavy and compact subsoils, but they are sufficiently well drained to permit good growth. Although the Savannah and Franklinton soils have weakly cemented hardpans in the subsoil, they are moderately well drained.

Susquehanna is an example of a soil definitely unsuited to tung growing. Close to the surface of this soil is a subsoil of highly mottled, red, light-gray, and brown clay, plastic and sticky when wet, and extremely hard when dry. The internal drainage is entirely inadequate, and trees planted on this soil grow poorly, if at all. The same is true of Caddo very fine sandy loam, which is found in upland flats. Tung does poorly also on Leon and Fellowship soils in peninsular Florida because of poor drainage.

In Mississippi and Louisiana, Pheba and Lewiston fine sandy loams have been planted extensively to tung. These soils are not satisfactory, because hardpans within 12 to 30 inches of the surface seriously restrict drainage.

Large acreages of tung have been planted on deep sandy soils such as Lakeland and Blanton fine sand, but many of these orchards have failed. These soils are low in moisture- and fertilizer-holding capacity, and orchards planted on them usually require a long time to come into profitable production. Under some conditions these soils may produce profitable tung orchards, but it is always preferable to plant on soils of better moisture-holding capacity and higher fertility.

Preparations for Planting

If cut-over land is selected for the orchard, the first task is to clear it. This involves removing all stumps, brush, and litter.

Land may be prepared for planting by plowing and disking either the entire field or rows 12 to 18 feet wide where trees are to be planted. Preparation in the rows should be thorough so that cultivation of the trees later on will not be difficult.

Because tung is grown in an area of heavy rainfall, tree rows should follow the contour of the land, and slopes of 3 percent or more should be terraced.

Terraces between rows of trees interfere with cultivation in the mature orchard. Planting on the terraces promotes tree growth and production by providing more topsoil and better soil aeration. However, young trees planted on the tops of high terraces often lack moisture and make poor growth. A good plan is to plant the trees in rows at proper contours and build the terraces gradually by working the soil toward the trees for a year or two. This may be done safely provided sod is left, or cover crops are grown between the rows to prevent erosion before the terraces are completed.

Orchard terraces are normally not so high as terraces for general farming but are broader and more closely spaced. At the steepest point on the slope the terraces should be spaced at minimum tree-row intervals. From this point, they are projected in both directions by use of the engineer's level and

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rod, and the distance between them will grow wider where the slopes are not so steep.

It is important to remember that **the channels along which the water flows, not the tree rows themselves,** must be on the grades established by the engineer. The rows of trees are planted below the engineer's lines, allowing for the width of terrace bases to bring the channels at the proper places.

"Point rows" of trees may be planted between the terraces where space permits. Cultivation will build up soil along the point rows, and eventually they will serve as terraces. Because of this, **point rows must follow a continuous downward grade** toward the next lower terrace or the outlet. As one proceeds toward the outlet, point rows should follow the lower terrace if the terraces are diverging, and follow the upper terrace if terraces are converging.

The following method simplifies laying off the point rows: A ball of twine is used with streamers tied to mark the proper intervals between rows; for example, at 35-foot intervals. Starting at the beginning point of water flow, one person takes the ball of twine and walks the upper terrace toward the outlet. Another person takes the end of the string and walks the adjacent (lower) terrace, keeping abreast of the one on the upper terrace. As they proceed toward to outlet, the person on the upper terrace may unwind string but never rewind it, and the one on the lower terrace may take up slack but never give back any string. As these two persons walk the terraces, other persons should follow the streamers, setting stakes at convenient intervals to mark the tree rows.

Tung may be planted on land that has standard field terraces of broad base and proper grade. Full rows of trees should be planted on the terraces; and point rows, planted between, are laid out as described above.

If standard field terraces are closer than the minimum distance required between tung rows, the slope is probably too steep for planting tung. This also holds true if, in constructing new terraces at minimum spacing, it is found that the drop in elevation from one terrace to the next lower terrace is greater than can be allowed for the soil type, expected rainfall, and cultural conditions.

Diversification

Almost every tung-producing farm contains some acreage that is unfit for tung production. Fuller use of the land can be obtained by producing crops in addtion to the tung trees. Certain pasture grasses, legumes, or combinations of these can be planted to establish pastures on land unsuited for tung. It does not pay to have the permanent pasture in the orchard, but after the trees are 3 or 4 years old, leguminous cover crops growing in the orchard may be grazed to a limited extent.

Many companion crops can be grown in a tung orchard while the trees have not yet fully occupied the land. Some satisfactory crops for this purpose are clovers for hay or seed, cotton, strawberries, peanuts, sweet corn, sweetpotatoes, field peas, beans, cabbage, and melons. Tall-growing crops should not be planted so closely that they will shade the young trees.

The county agricultural agent should be consulted for further information on the growing of companion crops, the establishment of permanent pastures, or production of beef. Another source of information on local problems is the State agricultural experiment station. Publications of the United States Department of Agriculture are also available to the farmer.

PLANTING STOCK

Seedlings and Budded Trees

Nearly all of the commercial tung orchards in the United States were started with seedlings, although 200,000 to 300,000 budded trees were also used.

Seedlings generally differ considerably from the parent trees in their growth and fruiting characteristics. In the process of seed formation, a redistribution of characters takes place so that those inherited by one seedling are never all identical with those of another. Seedling progenies of plants that have been self-pollinated for several generations may rather uniformly resemble the parent, however. An average of less than 1 out of 100 selected "mother" tung trees will produce seedlings sufficiently uniform and otherwise suitable for commercial planting. To tell whether a selected tree will make a satisfactory source of seed, one has to grow a large number of its seedlings to maturity and then judge the parent by the characteristics of the seedlings. This is called a progeny test, and only trees so tested should be used as sources of seed for planting commercial orchards.

A "mother" tree proved worthy by progeny testing may be propagated by budding. The budded trees, which are hereditarily identical with the original tree, will provide an adequate supply of seed satisfactory for planting.

Seedlings are used to provide a root system for budded trees. Buds from "mother" trees are inserted in the stems of 1-year-old seedlings 2 or 3 inches above the surface of the soil. Later, the original seedling top is cut off and a new top is grown from the transplanted bud. Thus, the tops of the budded trees are parts of the parent trees, and the mature budded trees exhibit the same characteristics as the parent trees. Characteristics of the seedling roots may sometimes affect rate and extent of growth and fruitfulness of the budded trees, however.

In experiments of the United States Department of Agriculture, seedlings from the best progeny-tested parents are compared with budded trees of the same parentage. Up to 10 years of age, the seedlings have outgrown the budded trees and, on the average, have produced considerably larger crops. Budded trees of some varieties like La Crosse differ little from the seedlings, but those of other varieties like Folsom are greatly inferior to the seedlings. The budded trees are somewhat more uniform than the seedlings in productivity, oil content, and date of maturity of the fruit. The oil content of the whole tung fruit varies inversely to its moisture content. Oil-content data in this bulletin are based on a 15-percent moisture content typical of thoroughly air-dried fruit.

The United States Department of Agriculture has released five varieties of tung trees, seedlings of which are planted commercially. These are:

Folsom.—A low-heading variety of high productivity. The fruits are large, mature late, turn purplish as they approach maturity, and contain about 21 percent oil. This variety has a high degree of resistance to low temperatures in the fall, a valuable characteristic because the embryonic blossom buds for the next year's crop are sometimes killed at that time of year.

Gahl.—A low-heading, productive variety that bears large fruits with an oil content of 20 percent or slightly more. This variety matures early and has proved somewhat resistant to cold in the fall.

Isabel.—A very popular, low-heading variety of high productivity. It bears large fruits, which

mature early and contain about 22 percent oil.

La Crosse.—A high-heading variety of exceptional productivity. The fruits are small, mature late in the season, and tend to break into segments if not harvested promptly, but have an oil content of 21 to 22 percent. The variety is popular with many growers, especially those who dislike to cultivate low-heading trees.

Lampton.—In tests, this variety has outyielded all others. It is a very low-heading tree, which bears large, early maturing fruits of about 22 percent oil content. If the trees are overloaded, the oil content may be considerably lower.

First-generation seedlings of Folsom, Lampton, and La Crosse are very true to parent type. Gahl and Isabel produce 25 to 30 percent of off-type seedlings. These off-type seedlings are worthless for planting and should be destroyed. They can be detected in the nursery; only the true-to-type seedlings should be planted.

Seedlings of a selection known as L–46, of selections made by the Florida Agricultural Experiment Station known as F–2 and F–9, and of a tree called the McKee, have been widely planted. At the time, they were among the best trees available. However, it is believed that none of these is now equal to the newer varieties released.

Every effort should be made to obtain first-generation seed for planting; that is, seed from the original tree or from budded trees propagated from the original tree (fig. 4). In recent years, demand for seed of the new varieties released by the United States Department of Agriculture often exceeded

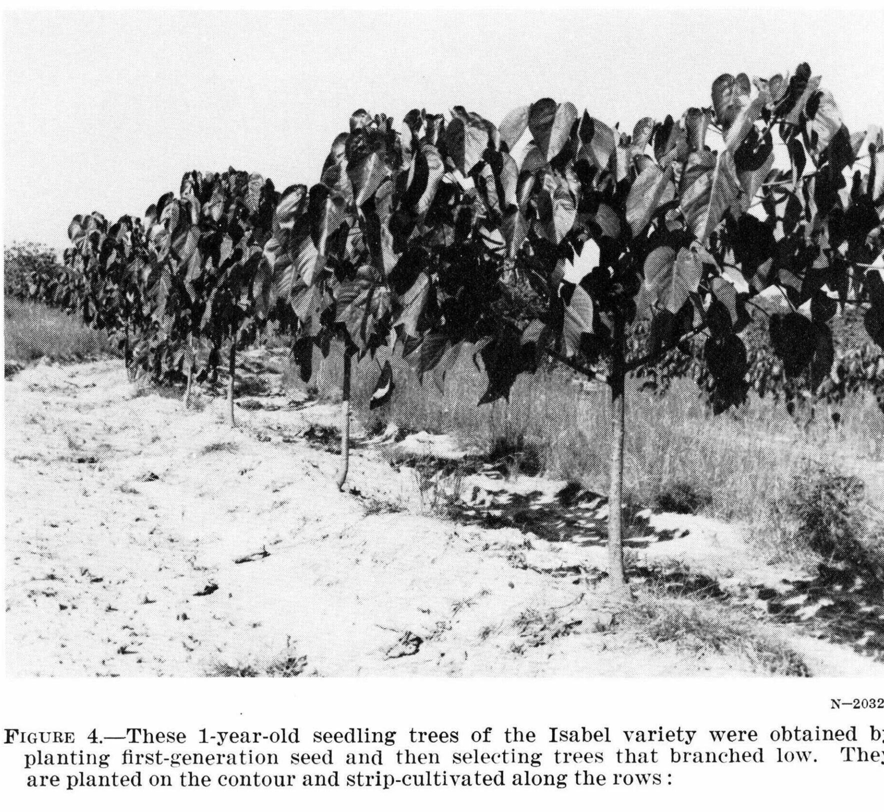

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FIGURE 4.—These 1-year-old seedling trees of the Isabel variety were obtained by planting first-generation seed and then selecting trees that branched low. They are planted on the contour and strip-cultivated along the rows:

the supply. Only small quantities of seed from the original tree, or from budded trees, were available. Because of this, many growers have used seed from seedlings of the original tree (second-generation seed). On the basis of natural laws of inheritance, it was anticipated that the variations observed in seedlings from the original trees would tend to increase in successive generations. Results with tung trees grown from second-generation seed confirm this view.

The Nursery

A supply of the progeny-tested seed should be arranged for well in advance of nursery-planting time. Requirements for a nursery site are basically the same as those for an orchard. The site should be in an upland location so that air drainage will reduce the risk of cold injury to the young plants; the soil should be friable, well-drained, have an adequate moisture- and nutrient-holding capacity, and be reasonably fertile. The site should be plowed in the fall and harrowed three or four times in the spring before seed is planted.

Tung seed is normally short-lived and must be planted during the season following its harvest. It pays to hull the seed before planting rather than to plant segments, each consisting of a seed and the adhering hull. Leaving the hull on the seed retards germination.

Hulled seed may be planted dry. However, earlier germination may be obtained by soaking the seed in water for 5 to 7 days before planting. Stratification, cold treatment, or chemical treatment will effect still more rapid and uniform germination.

In stratification, seed is placed in moist sand as soon as possible after harvest (not later than the last of December), and left outdoors until planting time. A pit 15 to 18 inches deep is dug in a level, well-drained, preferably shaded site. An above-ground wooden frame of the same depth may be used but is less desirable, because temperatures inside it will vary more. In either case, a 3-inch layer of clean, moderately coarse sand is placed in the bottom. Single layers of hulled seed are alternated with ½- to ¾-inch layers of sand until the bed is nearly full. It is then capped with 6 inches of sand. Stratified seeds must be inspected frequently in March and planted before they germinate.

In cold treatment, the hulled seeds are placed in moist wood shavings and kept at a temperature of about 45° F. in a cold-storage room for 30 to 40 days before planting. The effect of this treatment is much the same as that of stratification.

Chemical treatment also accelerates germination but somewhat less effectively than stratification or cold treatment. The best chemical treatment consists of soaking the hulled seed in 1-percent morpholine solution in a nonmetal container for 48 hours before planting. The advantage of the cold treatment or chemical treatment over stratification is that less time is required and there is no danger of premature germination; planting can be done whenever weather and soil conditions are favorable.

Dry-stored seed should be planted early, not later than February. Stratified seed should be planted about the middle of March. The cold-treated or chemically treated seed may be planted advantageously as late as the first week in April, excepting in localities subject to spring drought. In those areas, it is advisable to plant early enough for germination to be completed and growth well started before the dry weather begins. The seeds are usually planted either by hand or with a modified corn planter. They are spaced 6 to 8 inches apart and placed about 2 inches deep in rows

48 or more inches apart, depending on the equipment to be used in cultivating and digging the trees.

The nursery must be kept free of grass and weeds during the growing season if large, superior-quality seedling trees are to be produced.

Seedlings from dry seeds generally do not come up for 60 days or more, and weed control often becomes a serious problem. For this reason, newly cleared land that is relatively weed-free is preferred for a dry-seeded nursery. Seed is sometimes planted 4 or 5 inches deep under "beds" of soil thrown up with a "middle buster" or single-disk harrow. The extra soil is "barred off" with a drag or spike-tooth harrow just before the tung seedlings are expected to come up, thus destroying weeds.

The use of stratified, cold-treated, or chemically treated seed, which is planted late, makes it possible to kill the weeds by disking repeatedly for 4 to 6 weeks before planting. The rapid and uniform germination effected by these treatments permits easier weed control because the barring-off, hoeing, and cultivation may be started soon after the planting date.

The application of 6 pounds (acid equivalent) of 2,4-D (2,4-Dichlorophenoxyacetic acid) per acre is recommended as a preemergence treatment. The 2,4-D is diluted in about 100 gallons of water and sprayed evenly over the surface of the soil, not less than 7 nor more than 14 days after planting the tung seed. By this means, growth of grass and weeds is retarded without injury to the tung seedlings, and much less hoeing is required.

As soon as the seedlings can be seen, they are side-dressed with fertilizer, the amount and composition of which will depend somewhat on the soil. In the western part of the Tung Belt, nitrogen and phosphorus are the two most important elements required, but it is customary to use 5–10–5 fertilizer, having 180 pounds of commercial zinc sulphate incorporated in each ton. The fertilizer is applied at the rate of 600 pounds per acre (which is about 6 pounds per 100 feet of row) in bands along each side of the row, 8 inches from the seedlings and 2 to 3 inches deep. On light-textured soils in the eastern part of the Tung Belt, such as Lakeland fine sand, a mixed fertilizer of 6–6–6 or 8–8–8 composition is preferred, and the mixture should also contain zinc (3 percent), magnesium (3 percent), copper (0.4 percent), and manganese (0.4 percent).

Budding

Budded trees are required in order to meet the needs for first-generation seed. Budding is done by the simple, effective, shield method. This requires a piece of budstick bark, including a bud, that will fit into a cut in the rootstock bark.

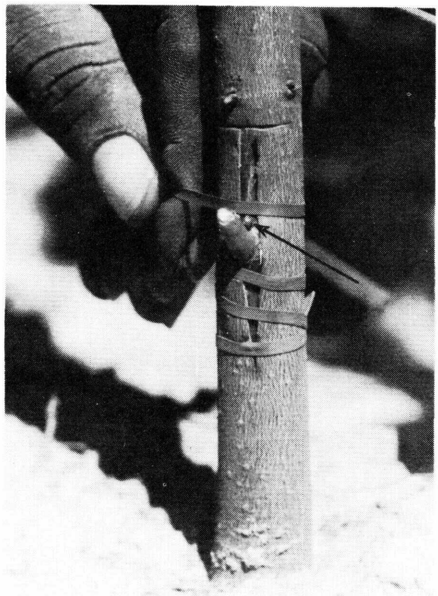
Just before they are to be used, vigorous budwood shoots of the current season are cut from mature trees or from nursery stock that is true to variety. The leaf blades are cut from the budsticks, leaving a short piece of petiole (leafstalk). If buds form, they are always in the axils (upper angle between the petiole and the stem) of the leaves. After preparation, the budsticks should be wrapped in a damp cloth to prevent drying. At the time of budding, shield-shaped pieces of bark, including the bud, are cut from the budsticks.

A **T**-shaped cut, large enough to receive the budstick shield, is then made in the bark of the rootstock at a point 2 or 3 inches from the ground. The flaps of bark are loosened. With the petiole used as a handle, the shield-bud is now slipped inside the flaps of bark on the rootstock. The flaps are tied down tightly over the transplanted bud with a rubber budding strip (fig. 5). Strips 5 inches long, 3/16

inch wide, and 0.016 inch thick are recommended.

After about 7 days, the rubber strip is cut to prevent binding the bud too tightly as the rootstock increases in size. Budding is most successful when the rootstocks are in active growth. The best period for budding is generally late August when the seedlings have attained good size and are still growing vigorously. As the newly set buds are susceptible to cold injury, soil is mounded over them before cold weather begins. When growth starts in the spring, the soil is pulled away, and each stock is cut back to within an inch and a half of the dormant bud in order to force it into growth. Later care consists of keeping all suckers removed and the trees well cultivated. The trees are transplanted to the orchard late the following winter.

Spring budding is done just as soon as the bark of the budsticks and rootstocks will slip; the buds are forced as soon as they have set, usually about 10 days to 2 weeks after the budding operation. Budding is done in the spring only as a last resort if the necessary trees were not propagated the previous fall.



N–20327

FIGURE 5.—This shield-bud, or T-bud, has been inserted under the flaps of bark on the rootstock and is being wrapped with a rubber budding strip. Bud is indicated by arrow.

PLANTING THE ORCHARD

The number of trees planted per acre may vary from 50 to 300. The tung tree bears only on the ends of shoots produced the previous year and largely in the outer portions of the tree. When the trees are small, close planting in the row greatly increases the bearing surface, but at maturity the bearing surface of a crowded, or "hedge," row is about the same as that of a row in which the trees are farther apart. Close planting in the row will increase early yields and also shade out weeds and grass between the trees. It is well to leave enough room between rows for orchard operations, however.

In contour plantings, distances between rows and total number of trees per acre vary. Rows 30 to 35 feet apart with trees spaced 10 to 12 feet in the row will give about 100 to 140 trees per acre, which will provide reasonable production at an early age with adequate room for cultivating and harvesting. The best distance depends also on economic considerations that vary with the individual grower. For example, a grower engaged in beef production as a companion enterprise might plant near the hilltops in rows 25 feet apart in order to obtain early high yields of tung and at the same time have more room for pastures in the bottoms.

The cost of land, clearing, planting stock, and care must be considered. Since an acre of 300 closely

planted trees is worth no more at 7 or 8 years of age than an acre of 140 trees, the total acres of bearing orchard that may be had for a given initial investment is a major consideration. Total production from the mature orchards will be about the same, and a smaller investment will have been made in the orchard with the more widely spaced trees.

The orchard should be planted with nursery stock or seed in January, February, or March. As a rule, growers will obtain the most satisfactory results by planting selected nursery trees. The cost of growing seedlings in a nursery and then transplanting them is greater than planting seed directly in the field, but savings are gained in the cost of cultivation for the first year. Planting seed in the orchard requires intensive cultivation of the whole orchard to insure adequate tree growth and good branch structure. Also, when seed is planted in the orchard, the opportunity to select the best type of seedling is limited.

If nursery stock is used, it will pay to discard all trees not true to type, because even the best seed produces some poor trees that will be consistently unprofitable if transplanted to the orchard.

Nursery trees can be dug by hand or with a commercial nursery-tree digger. The main roots should be severed about 1 foot below the surface of the ground and the lateral roots about 10 inches from the trunk. The roots should not be exposed long to the air. Trees that are to be transported for some distance should be packed well with damp hay, straw, or similar mate-

N–20328

FIGURE 6.—A 20-inch, tractor-driven auger quickly digs holes for planting tung trees. The operator drops a tree by the hole, moves along the length of the chain, and repeats the operation.

rial. If is is not convenient to plant immediately at the orchard site, the trees may be heeled in by covering the roots with earth, taking care to leave no air pockets. Heeled-in trees must be planted before growth starts.

Trees should be transplanted to the same depth they were in the nursery, or 1 or 2 inches deeper. Transplanting holes may be dug by hand or mechanically (fig. 6). If an auger-type machine is not available, a lister or "middle buster" may be used to open a deep furrow that will save much of the labor of digging holes. The holes should be large enough to accomodate the root system without crowding or further pruning.

Two men can work together very effectively in transplanting trees. As one man shovels, the second man can hold the tree at the proper depth, continually working the soil in around the roots and moving or "jiggling" the tree to insure even packing. It is important to start packing the soil around the roots with the first shovelful of earth.

PRUNING AND TRAINING

Natural-Form Training

The tops of nursery trees must be pruned back to 8 to 10 inches at planting. Otherwise, growth is unsatisfactory, and a weak framework of branches is formed. As growth starts, all buds are rubbed off except the one strongest growing and best placed on each tree. A bud that starts 2 inches or more below the top of the stump is preferred over one closer to the top. Forcing the growth into one bud should result in a "natural-form" type of tree, well branched at the end of the first year (figs. 7 and 8).

Vase-Form Training

If conditions during the first growing season in the orchard are unfavorable, the trees may fail to branch. If so, they usually throw out a whorl of four or five lateral branches from growing points within the terminal bud when growth starts the second year. Known as "cartwheels," these trees are structurally weak and often break under the strain of heavy crops and high winds. To prevent such growth, the unbranched trees are cut back to a height of 16 to 18 inches at the beginning of the second season. All buds that force out are allowed to grow, forming what is known as a vase-form type of tree.

Training to vase form at planting time will bring about the highest yields per tree, but the same production per acre may be had by planting a larger number of trees and training them to natural form. Although stronger than the "cartwheel" tree, a vase-form tree is weaker than a natural-form tree. Therefore, vase-form training is recommended only if the tree fails to form a good natural head during the first year in the orchard or if the natural head is damaged, for instance, by cold injury.

Figure 9 shows an ideally branched tung tree; figure 10 shows one that is poorly formed; and figure 11 shows the effect of a weak branch-to-trunk union.

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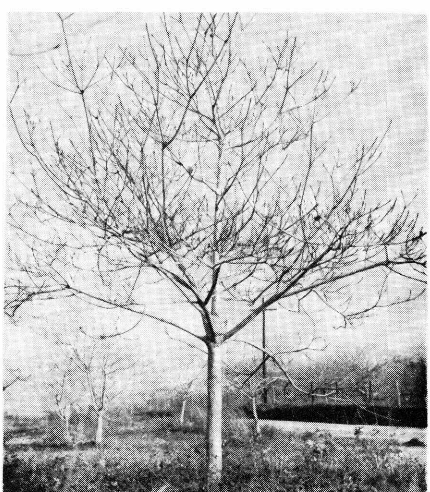
N—20329

Figure 7.—Low-heading tree of the Lampton variety (left) and high-heading tree of the Lamont variety (right), trained to natural form, as they appeared at the close of the first season in the orchard. Trees of low-heading varieties generally start bearing sooner than those of high-heading varieties.

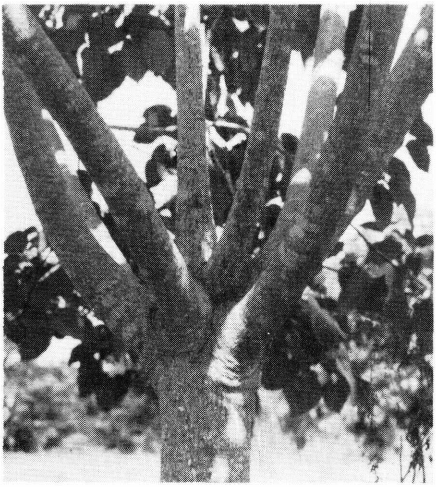


N—20330

Figure 8.—A 7-year-old seedling tree of La Crosse, a high-heading variety.

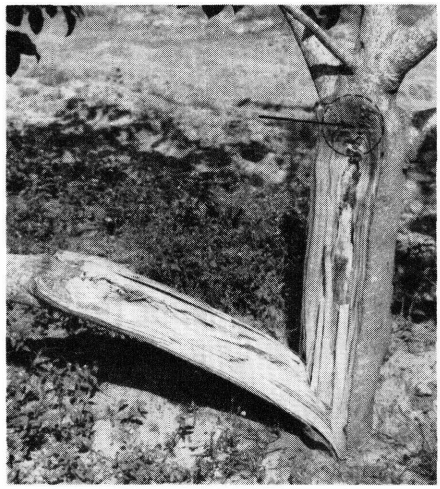
N—20331

Figure 9.—The framework of this tree shows elements of strength: The branches are well spaced along the trunk, there is a wide angle between the branches and the main trunk, and the leader branch is large.



N–20332

FIGURE 10.—Elements of weakness are shown in the framework of this tree: The branches are crowded near one point on the main trunk, there is an acute angle between the branches and the trunk, and there is no strong leader branch.



N–20333

FIGURE 11.—A weak union results when a branch makes a sharp angle with the trunk. Note triangle of bark at the crotch (circled), showing extent of separation of branch from trunk before the split occurred.

CULTIVATION AND COVER CROPS

For best growth, young trees must be kept free from competition with weeds and grass from April to the end of June (fig. 12). There is reason to believe that the same is true of bearing tung orchards.

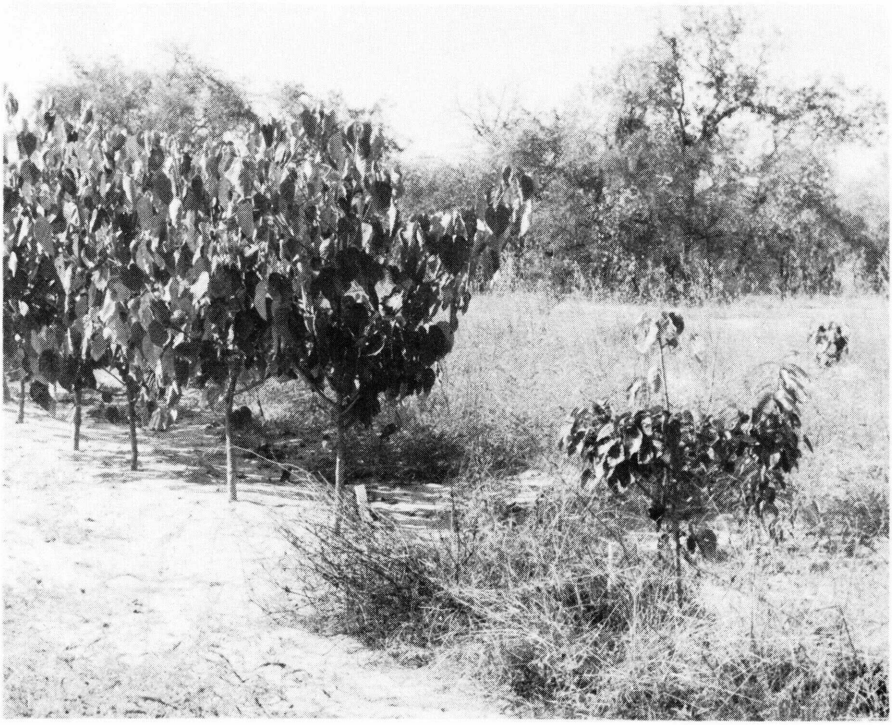
Also, for success in tung culture, it is advantageous to grow and to incorporate into the soil a leguminous green-manure or cover crop.

In young orchards, the grower has a choice of using either a summer cover crop (table 1) or a winter cover crop (table 2), and the schedule of annual cultivation will depend largely upon this choice.

Summer legumes grow vigorously and if planted by the middle of June will generally produce a satisfactory tonnage of green manure by the middle of August. At that time, strips next to the tree rows are cultivated, leaving the cover crops in the middles between the rows (fig. 13). This facilitates harvesting and prevents the cover crop from competing with the trees for moisture during the fall when precipitation is usually at a minimum.

Strips of a cover crop like crotalaria, remaining in the middle of the rows, will reseed the entire area. Cover crops such as alyceclover will provide seed for replanting the strips next to the tree rows. Unplowed strips also protect the soil against erosion during the winter.

The use of summer cover crops permits the tung grower to avail himself of a certain degree of spring frost protection that cannot be had in orchards planted to winter cover crops. If all vegetation and fallen leaves are plowed under by the end of February, the ground can settle before the danger period. The soil then absorbs heat during a sunny day and gives if off during the following night. Heat is absorbed only if the surface is free from trash. In order to form an effec-



N—20334

FIGURE 12.—Trees of the Lampton variety at end of second growing season in the orchard. Trees on the left were kept free of competing grass and weeds from time of planting, whereas tree on the right was uncultivated.

tive heat reservoir, the soil must be solid enough so that heat striking the surface will be conducted downward a foot or 18 inches.

If the air temperature is near the critical point, a very little heat may save the crop. Because tung is planted on slopes and the cold air drains to the bottoms, some part of the slope is likely to be at the critical temperature on almost any frosty night.

The cultural schedule that includes summer cover crops should be arranged so that the crops will make their growth during the summer months when rainfall is usually heaviest. Cultivation of the orchard should begin in early spring, frequently as early as late January or, in any case, by early March, and should continue intensively until about the middle of June.

Evidence from tung cultivation tests indicates that the principal benefit from cultivation is the elimination of grass and weeds (see fig. 13). Therefore, shallow cultivation, just deep enough to destroy this competing growth, is desired.

If a mulch deep enough to kill out grass and weeds is used, young tung trees grow just as well or better than if intensive cultivation is practiced. Mulching is especially valuable for "replants"—young trees set out where older trees have died. As a rule, it is difficult if not impossible to properly cultivate and hoe replants scattered here and there among large trees in an extensive orchard. A deep mulch of hay extending 25 to 30 inches on

TABLE 1.—*Principal summer cover crops*

Common name	Scientific name	Planting date	Seeding rate per acre		Turning date
			Drilled	Broadcast	
			Pounds	*Pounds*	
Alyceclover	*Alysicarpus vaginalis*	June or early July [1]	10	15	August to September.
Beggarweed	*Desmodium purpureum*	June [1]		10–15	Do.
Cowpeas	*Vigna sinensis*	May to June	25	60–90	Do.
Crotalaria	*Crotalaria intermedia*	June [1]		10–15	Do.
	C. lanceolata	do		8–12	Do.
	C. mucronata [2]	do		10–20	Do.
	C. spectabilis	do		15–25	Do.
Hairy Indigo	*Indigofera hirsuta*	June		6–10	Do.

[1] There should be volunteer stands after the first seeding.
[2] Formerly *C. striata.*

TABLE 2.—*Principal winter cover crops*

Common name	Scientific name	Planting date	Seeding rate per acre		Turning date
			Drilled	Broadcast	
			Pounds	*Pounds*	
Austrian winter peas	*Pisum arvense*	October	25–35	40–60	April.
Blue lupine [1]	*Lupinus angustifolius*	do	50	100	April to May.
Common vetch	*Vicia sativa*	do	25	40–50	Do.
Crimson clover (reseeding)	*Trifolium incarnatum*	October [2]	20	20–25	May.
Hairy vetch	*Vicia villosa*	do	20	20–30	April to May.
White clover	*Trifolium repens*	October [2]	4–6	4–6	Do.

[1] Seed should be covered to a depth of 2 inches.
[2] There should be volunteer stands after the first seeding.

N—20335

FIGURE 13.—This summer cover crop of alyceclover was turned under along the tree rows to prevent competition for moisture during the dry fall months, and to facilitate the harvest.

all sides of the tree may be applied at planting time and will insure satisfactory growth with no further attention. A mulch of tung hulls perhaps 6 inches deep is fairly satisfactory, and paper fertilizer bags may be used **if care is taken to arrange them so that they carry the rain toward, not away from, the trees.**

In older tung orchards, grass and weeds are often killed out by shade. In fact, when the trees are large enough to form a complete canopy over the soil, there is very little competing growth and little cultivation is required. Such orchards need cultivation only to work fertilizer into the soil in the spring. There is reason to believe that additional cultivation would be detrimental. Because no cover crops can be grown in such complete shade, fallen leaves are the only source of green manure for the soil. Hence, losses of soil organic matter need to be kept at a minimum by avoiding unnecessary cultivation.

Method of cultivation and choice of implements depend mostly on orchard conditions and the grower's preference.

Row-crop equipment, either horse- or tractor-drawn, may be used to advantage in the newly planted orchard. When the trees are first planted the rows may be straddled and later in the season the row-crop cultivator may be operated on each side of the tree rows. If cultivation fails to control weed growth completely, the trees must be hoed. Power hoes (tractor attachment) may be used.

In older orchards the first operation of the season is generally the turning under of a cover crop, for which the disk tiller, wheatland plow, or the one-way disk plow (fig. 14) may be used. This work is often done by using an offset disk harrow (fig. 15). Land between tree rows may be worked with a tandem disk.

For the maintenance cultivation that follows, a spring-tooth harrow (fig. 16) is an excellent implement that may be used to cover a large number of acres daily at low cost. This harrow is not suited to destroying heavy weed growth, however, and unless cultivation is frequent some type of disk is preferable.

Volunteer tung trees and blackberry briars growing in the tree rows are not controlled by machine cultivation. They must either be hoed out by hand or killed by spraying with herbicides. Although the herbicide used, 2,4,5-T (2,4,5-Trichlorophenoxyacetic acid), is rather expensive, comparatively little labor is required, and the total cost of spraying is generally about the same as that of hand hoeing. When hoed out, both tung volunteers and briars, especially the briars, tend to sprout from pieces of root left in the soil, but spraying kills both top and root.

The 2,4,5-T is manufactured in different forms. Some are volatile like an alcohol-base antifreeze for automobile radiators, and some are low-volatile like a permanent antifreeze. It is essential to use a formulation of low-volatile esters, sold as a concentrated liquid. The active agent should be stated in

N–20336

FIGURE 14.—This tractor with guard is being worked close to the tree row with a one-way disk plow. The guard rarely damages the tung branches.

N–20337

Figure 15.—The offset disk harrow is ideal for cultivation under the branches of tung trees.

"pounds of acid equivalent" per gallon of concentrate. Each 100 gallons of diluted spray material should contain 3 pounds of acid equivalent. Because a fine mist would tend to drift into the bearing trees and injure the foliage, the diluted material is applied as a coarse spray at a pressure not exceeding 40 pounds per square inch. If properly used in strict accordance with these instructions, there is no danger of injury to the bearing trees, other crops, or livestock. The spraying may be done at any time after the tung seedlings and briars have developed full foliage up to the end of June.

The poisoning of cattle from eating green and partially dried leaves from cut tung branches has been reported. However, no trouble from poisoning has been experienced in July and August, when tung volunteers are usually cut. At that season the animals have plenty of other food which they prefer to tung leaves.

Summer Cover Crops

Excellent summer cover crops can be grown throughout the whole Tung Belt (table 1). Among those most commonly grown are four species of crotalaria—*Crotalaria intermedia*, *C. mucronata* (formerly *C. striata*), *C. lanceolata*, and *C. spectabilis*—and alyceclover. The *spectabilis* species of crotalaria is highly satisfactory for the production of green manure and is the only cover crop that can be recommended for use in unfenced orchards of open range country. Although *C. spectabilis* is poisonous to cattle, they will not readily eat it.

On some of the lighter tung soils of Alabama, Georgia, and Florida, beggarweed makes a rather satisfactory summer cover crop. Hairy indigo has been used in a limited way and has produced good stands, even on sandy soils. Soybeans or cowpeas may also be used. Common

N–20338

FIGURE 16.—Following the initial cultivation with a disk harrow, frequent use of the spring-tooth harrow shown above will keep the soil in good tilth at minimum cost.

lespedeza has been tried in some orchards, particularly where growers have hoped to provide pasture between the rows of trees. However, this crop forms a tight sod early in the season, when the tung trees are in the greatest need of cultivation, and has seriously restricted tree growth and fruit production wherever it has been used.

It is sometimes advantageous to mow the summer cover crop rather than to disk it under. Weed choppers are efficient implements for this work. Because of their trouble-free performance, they are generally favored over conventional mowing machines, which are frequently broken when operated in orchards. The rotary pasture mowers are very satisfactory for orchard use.

A type of weed chopper that tapers from one end to the other, giving a slicing action to the cylinder, cuts weeds effectively. In unterraced orchards, this implement seems to be excellent for fitting the land for harvest.

The disk harrow, shown in figure 15, is more widely used than the cover crop chopper.

Winter Cover Crops

Most winter cover crops (table 2) grow rather slowly during the winter months, making the major part of their growth in early spring at about the time the tung trees are coming into leaf. They are particularly useful in orchards of large trees where the intense shade of fully developed tung foliage in mid-

summer precludes the growth of summer cover crops. Most of the winter cover crops must be seeded annually. When such crops are used, a recommended rotation would include hairy vetch, common vetch, and Austrian winter peas. Blue lupine should be included in the rotation in those areas where it can be grown, as in the more sandy soils of the tung-producing areas of Alabama, Georgia, and Florida.

Because tung fruits drop to the ground at the season when winter cover crops are sown, a satisfactory self-seeding winter cover crop is of great value to tung orchardists. The Dixie and Autauga varieties of crimson clover, and common white clover are used by some tung growers as self-seeding winter cover crops. Only certified seed should be purchased as distinction cannot be made between reseeding and nonreseeding crimson clover varieties. As a rule, the seeds do not mature until late in the season; therefore, the early cultivation so essential to the tung orchard must be sacrificed. Under favorable conditions, white clover or crimson clover may make a heavy mat over the surface of the ground. This suppresses other growth and acts as a mulch, making early cultivation less essential. In fact, some orchardists who have heavy crimson clover in their orchards cultivate only in late summer to prepare for harvest and to make a good seedbed for the reseeding clover. During early summer, the clover provides an effective mulch, and subsequently, grass growing through the mulch is mowed or pastured off. In orchards on deep, well-drained soils, this system of soil management appears to be quite satisfactory.

Cover-Crop Fertilizers

To grow cover crops successfully, proper soil conditions must be provided and suitable fertilizers applied. As pointed out on page 6, most soils in the tung-producing area are too acid for the best growth of cover crops, especially legumes.

For satisfactory stands of cover crops, an application of 1,000 pounds per acre of dolomitic lime should be made annually on most soils until the pH, or acidity measurement, of the soil reaches 6.0 to 6.5. After that, the dolomitic lime should be applied less frequently. Agronomists sometimes recommend the application of large amounts of dolomite at one time, the quantity which soil acidity tests indicate is necessary to bring the pH of the soil up to 6.0 to 6.5. This practice is perfectly satisfactory in tung orchards. Dolomitic lime supplies calcium and magnesium, which are required by both the cover crops and the tung trees.

Cover crops, especially legumes, will make little growth unless they are liberally fertilized with phosphorus.

If basic slag can be obtained, it should be applied at the rate of 500 pounds per acre at the time of seeding the cover crop. When basic slag is applied, it is not necessary or desirable to apply the dolomitic lime unless the soil is very acid, because the slag contains considerable calcium and a smaller amount of magnesium. Basic slag is not toxic to the seed or to the inoculum on the seed and, therefore, may be distributed and worked into the soil at the time of cover-crop seeding.

If basic slag is not available, 200 to 250 pounds of 20-percent superphosphate will, as a rule, produce excellent cover-crop growth. A good rule to follow is to apply the superphosphate and lime and work them into the soil 1 to 2 weeks before seeding the cover crop.

FERTILIZER REQUIREMENTS

Nonbearing Trees

The height of head and the number and distribution of the primary lateral branches of a tung tree are determined during the first year in the orchard. Good growth of a tung tree is especially important the first 4 to 6 years after planting in order that a strong framework may be formed and a large bearing surface attained as quickly as possible. Adequate cultivation is of major importance in producing satisfactory growth, but most soils on which tung is planted are inherently low in fertility, and good culture must be supplemented with proper fertilization.

Of the essential elements obtained by plants from the soil, nitrogen, phosphorus, and potassium are most likely to be deficient. The approximate average amounts of these elements required to bring a newly planted orchard into bearing are shown in table 3, on a per-tree and a per-acre basis for 100-, 125-, and 140-tree plantings.

On soils of the western part of the Tung Belt, nitrogen and phosphorus are essential for good growth of newly planted tung trees. Potassium applications are not always beneficial. A mixed fertilizer that supplies each tree with 0.06 to 0.08 pounds of nitrogen (N), 0.08 to 0.16 pounds of phosphorus (P_2O_5),

TABLE 3.—*Approximate average requirements of the essential elements nitrogen, phosphorus, and potassium per tree and per acre to bring a new tung orchard into bearing* [1]

ALABAMA, FLORIDA, AND GEORGIA [2]

Age of tree (years)	Formula [3]	Amount of fertilizer required in—					
		100-tree planting		125-tree planting		140-tree planting	
		Pounds/tree	*Pounds/acre*	*Pounds/tree*	*Pounds/acre*	*Pounds/tree*	*Pounds/acre*
Newly planted	6–6–6	1	100	1	125	1	140
1	6–6–6	2	200	2	250	2	280
2	10–5–12	3	300	3	375	3	420
3	10–5–12	4	400	4	500	4	560
LOUISIANA, MISSISSIPPI, AND TEXAS							
Newly planted	5–10–5	1	100	1	125	1	140
1	5–10–5	2	150	2	250	2	280
2	10–5–10	3	300	3	375	3	420
3	10–5–10	4	400	4	500	4	560

[1] In addition to nitrogen, phosphorus, and potassium, young tung trees require 2 to 4 ounces of zinc sulphate per tree annually for the first 3 or 4 years in the orchard.

[2] Additional requirements for this area: On light soils, magnesium (calculated as magnesium oxide (MgO)) applied at half the rate for potash. In certain areas, manganese and copper are also needed.

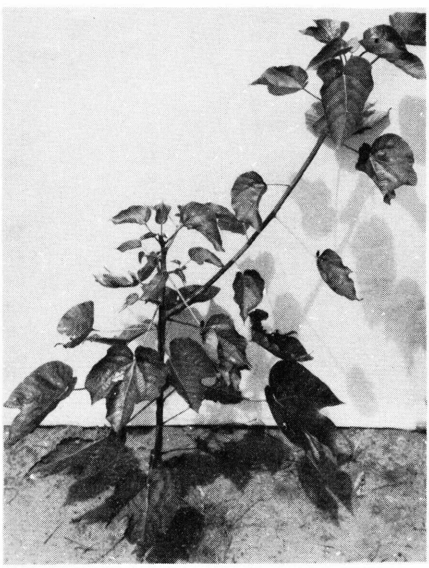
[3] Stated in percentages of nitrogen (N), phosphorus (calculated as phosphoric pentoxide, P_2O_5), and potassium (calculated as potassium oxide, K_2O). The difference between the sum of the percentages in the formula and 100 is made up by additional fertilizer elements or filler. Formulas, amounts, and fertilizer sources may be varied so long as equivalent amounts of the basic nutrients are supplied.

and 0.04 pounds of potassium (K_2O) gives consistently good results.

Of the ready-mixed commercial fertilizers now available, 1 pound of 5–10–5 fertilizer per tree most nearly approximates the needs for these three elements under average conditions in the Louisiana-Mississippi-Texas area.

In recent years, symptoms of deficiency of zinc have occurred frequently in newly planted orchards, especially on land previously used for growing general farm crops. Zinc-deficient tung trees make uneven growth, the leaves are sickle-shaped, and the areas between the veins lose their green color (fig. 17). When these symptoms are observed, 2 ounces of zinc sulfate per tree should be applied promptly.

At one year of age, the fertilizer application should be double that used at planting time. At two years of age (beginning the third year in the orchard), the trees start to bear and require higher levels of nitrogen and potassium but relatively less phosphorus. At that time, and until heavy bearing is attained, a fertilizer of 10–5–10 composition should be used. As they increase in size, the trees appear to be better able to obtain the required zinc from the soil. Yet, if zinc deficiency symptoms appear, zinc sulfate should be applied promptly.



N–20339

FIGURE 17.—This young tung tree shows uneven growth caused by zinc deficiency. The leaves tend to be sickle-shaped, and the areas between the veins have lost their green color.

Since soils in the eastern part of the Tung Belt are generally richer in phosphorus and poorer in potassium, magnesium, and some of the trace elements than are soils of the western part of the Tung Belt, less phosphorus and more potassium and zinc are recommended.

One pound of 6–6–6 fertilizer plus 3 ounces of commercial zinc sulfate per tree should result in good growth of newly planted trees in most soils in Alabama, Florida, and Georgia. However, Red Bay soils of this area are very low in potassium. Light-textured soils, such as Lakeland, are generally deficient in magnesium and, in some areas, also in manganese and copper. The fertilizer formula should be adjusted according to the locality.

When the tung tree is 1 year of age the amount of each nutrient in the fertilizer, except the zinc, should be doubled, and at 2 to 4 years of age the formula should be modified to provide the same zinc but relatively less phosphorus and more nitrogen and potassium. A 10–5–12 mixture, supplemented with magnesium, zinc, and other elements as needed, is satisfactory during this period.

Bearing Trees

Tung trees produce fruits only from the terminal buds of shoots of the preceding year. When the trees begin to bear heavily, shoot growth declines. More nitrogen is then needed to form a large number

of moderately vigorous shoots each year and thus provide for continued good crop production. Also, experiments have repeatedly demonstrated that liberal applications of nitrogen increase yields by increasing the number of pistillate flower buds formed in each terminal bud.

Potassium is used in large quantities by the bearing tree. High yields drain the potassium supply. A ton of fruit may remove 30 to 35 pounds of potassium (K_2O) from the orchard. Unless heavily bearing trees receive high levels of potassium, they become deficient in this element; dead spots then appear in the interveinal spaces and along the margins of the leaves, early defoliation takes place (fig. 18), and the trees become very susceptible to cold injury. Also, the oil content of the fruit declines seriously. Thus, potassium plays a major role in keeping bearing trees in good health and in developing and maintaining a high oil content in the fruit.

After the second or third year in the orchard, tung trees evidently can obtain a high proportion of the phosphorus needed from that occurring naturally in the soil and from phosphorus applied to cover crops. The proportion of phosphorus to other elements in the fertilizer may be reduced accordingly.

The fertilizer requirements of bearing trees are high and tend to be in proportion to yields. Orchards of the new varieties of tung trees (see page 9) bear very heavily and require more fertilizer than unselected seedlings of similar age. Thus, potential crop production is a better basis for fertilizer recommendations than age of tree. Fertilizer recommendations, based on size and productive capacity of the trees, are given in table 4.

No distinction is made between the eastern and western parts of the Tung Belt, because the amounts of fertilizer required by bearing trees are so large that differences in soil fertility between the eastern and western parts of the Tung Belt become of minor importance.

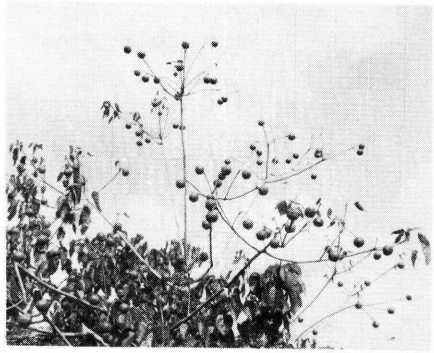


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FIGURE 18.—When tung trees are deficient in potassium the leaves scorch and fall, but the fruit hangs on.

The recommendations given in table 4 may be modified in accordance with local conditions. Tung growers must make sure that their trees make good shoot growth every year. The leaves should be of good size, dark green in color, and free from symptoms of malnutrition. Yields and oil content of the fruit will indicate whether the fertilization program is adequate. The amounts of each element used may be adjusted in accordance with these observations.

A chemical analysis of the tung leaves sampled in late July or early August is also helpful. Detailed directions for taking leaf samples must be carefully followed. The analyses are made by commercial laboratories. The approximate amount of each element that should be found in the leaves of healthy, vigorous, high-producing tung trees is shown in table 5. By means of leaf analyses made annually, a downward trend in leaf content of any element can be detected before deficiency symptoms appear. However, it must be emphasized that the criteria listed in the previous paragraph usually need to be taken

TABLE 4.—*Approximate average requirements of major fertilizer constituents, nitrogen, phosphorus, and potassium, for bearing tung orchards*

Estimated potential fruit production per acre	Amounts of fertilizer constituents		
	Nitrogen N	Phosphorus P_2O_5	Potassium K_2O
Tons	*Pounds/acre*	*Pounds/acre*	*Pounds/acre*
1	75- 80	40	90-100
1-2	100-120	60	140-160
2 or more	140-160	60	200-250

TABLE 5.—*Critical ranges*[1] *of nutrient elements in tung leaves sampled in late July or early August*

Element	Calculated as—	Leaf composition
		Percent
Nitrogen	N	2. 00-2. 50
Phosphorus	P	0. 14-0. 20
Potassium	K	0. 70-1. 00
Calcium	Ca	1. 00-2. 50
Magnesium	Mg	0. 25-0. 35
		Parts per million
Copper	Cu	4-5
Manganese	Mn	50-100
Zinc	Zn	25-35

[1] The range of leaf composition within which the tung plant behaves normally if other necessary elements are in balance. No beneficial effects result from increased content above the upper limits, and abnormalities occur with content below lower limits.

into consideration in order to interpret leaf analyses reliably.

When large amounts of fertilizer are used, it is often thrifty to purchase each element separately. Nitrogen may be purchased at minimum cost in liquid form as anhydrous ammonia (fig. 19), and phosphorus may be obtained most cheaply as basic slag or superphosphate. Potassium is purchased most cheaply as 60-percent muriate (potassium chloride). These fertilizer elements may be applied separately or as complete fertilizer mixtures.

Time and Method of Application

Because the root system of a tung tree is greatly reduced when it is transplanted from the nursery to the orchard, its ability to obtain the necessary nutrient elements from the soil is also reduced. Therefore, placement and time of application of the fertilizer are important. Experiments have shown that newly planted trees on the heavy-textured soils of the western part of the Tung Belt need only one application of fertilizer during the first year in the orchard. Since the in-

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FIGURE 19.—Anhydrous ammonia, injected into the soil with a machine like this, is the cheapest source of nitrogen for tung orchards. Note the metering pump just above the left rear wheel of the tractor.

itiation of growth takes place at about the same time in the roots as in the top, the fertilizer is best applied just as soon as the shoot buds break. On the other hand, present experimental evidence indicates that fertilizer should be applied twice to trees newly planted on sandy soils of the eastern part of the Tung Belt—once just as growth starts, and again 2 to 3 months later.

Regardless of location, fertilizer should be kept away from the tender, young roots that develop on trees just transplanted. It should be placed in a 3- to 4-inch band, the inner edge of which is 9 to 10 inches from the tree. On sandy soils where rain will readily wash the fertilizer downward, it is best to hoe the ground first and place the fertilizer on the surface. However, on soils of heavy texture, where heavy rains are likely to cause surface movement, it is best to hoe the fertilizer in, taking care not to move it toward the tree.

In bearing orchards, it is best to apply fertilizers at about blossom-time. However, excellent results are produced when nitrogen is applied much earlier, as in January. As has been indicated, there is considerable latitude in the choice of date for phosphorus application. This element may be applied in early spring to the trees, in June to a summer cover crop or native vegetation, or in the fall to a winter cover crop. When the cover crop decomposes, the phosphorus it has absorbed is released to the trees. The potassium may be applied to the trees in early spring with the nitrogen; or to the cover crop at

planting time, either in early summer or in the fall.

When the fertilizer is applied by hand, it should be spread evenly over an area that corresponds with the spread of the branches, but that is an ideal seldom even approached by the average workman. Many growers find that as soon as the trees form a continuous row, better distribution and lower costs are attained by spreading the fertilizer with a machine. A limespreader of the type used on general farms (fig. 20) is very satisfactory. These machines are usually 8 or 10 feet wide. With one side of the machine only in use, fertilizer is spread along each side of the row in bands 4 or 5 feet wide just inside the tips of the branches.

Fertilizer is sometimes spread on contract by operators who use large machines that pass once down each middle between tree rows, throwing the fertilizer toward the trees on either side. These machines rarely spread the fertilizer evenly; much of it drops close to the machine, where it promotes growth of grass and weeds to the detriment of the tung trees. Such machines are satisfactory only in orchards of trees so large that they shade out competing weed growth **from row to row.**

The tung tree has been relatively free from insects and diseases in the

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FIGURE 20.—The box-type limespreader is an excellent implement for fertilizing mature tung orchards. With only one-half of the machine in use, the fertilizer is placed evenly in a band 4 to 5 feet wide just beneath the tips of the branches.

United States. Grasshoppers sometimes eat holes in the leaves, and in a few instances the bollworm (*Heliothis armigera*) has attacked the young fruit. The larvae of the coffee bean weevil (*Araecerus fasiculatus*) sometimes infest the hulls of the nearly mature fruit, but without serious effects. Probably the most serious insect pests are the cottony-cushion scale (*Icerya purchasi*) and the oleander scale (*Aspidiotus hederae*).

Although infestations of the cottony-cushion scale occasionally cause tung growers much concern, the insect is readily controlled by the vedalia beetle (*Rodolia cardinalis*), which feeds on the scales. The beetles usually appear naturally when food is abundant. If they do not appear, they can be purchased from commercial sources.

The oleander scale is also attacked by some insects, but if infestation is severe it may be necessary to spray in late winter with an oil emulsion at the rate of 2 to 3 gallons of concentrate in water to make 100 gallons of spray material. If the application is thorough, practically complete control is effected without injury to the trees.

One of the relatively serious parasitic diseases of tung is thread blight (caused by *Corticium stevensii*). This parasite kills the leaves, which then hang suspended by the threads of fungus. The disease overwinters as a chestnut-brown, beadlike sclerotia (fungus sacs) on the twigs. If the infection is not extensive, the affected branches may be pruned out and burned. The disease may be readily controlled with bordeaux mixture applied once a year, preferably just after the fungus threads start to grow out from the overwintering sclerotia. If no control is practiced, yields of seriously infected orchards may be reduced 20 to 30 percent.

Nut rot (caused by *Botryosphaeria ribis*) has been known in the southern United States for at least 20 years. Fruits infected early in the season tend to drop prematurely and contain little or no oil. If infected late in the fall, the entire fruit may mummify and hang on the tree. These late-infected fruits are harvested with difficulty but are normal, or nearly normal, in oil content. No feasible control is known.

Black rot canker (caused by *Physalospora rhodina*) occurs principally on young trees, which may be killed back almost to the soil level. Later, new shoots develop just below the canker. Sometimes only a few of the upper branches are affected. The dead branches become ash gray in color, with numerous black perithecia (fruiting bodies) scattered over the surface. Pruning out and burning of diseased branches is advisable.

Clitocybe root rot (caused by *Clitocybe tabescens*), which occurs on native oak and other forest trees, may attack tung planted in newly cleared land. The infection on the root may spread slowly for several years, but in the final stages death comes quickly when the tree is in full leaf. The bark will be found to be dead at and just below the ground line, and a white mat of fungus threads may be seen between the bark and the wood. The disease characteristically kills a tree here, and another there, and sometimes small groups of trees, but has never destroyed an orchard. No feasible control is known, but it is inadvisable to replant in the same spot where a tree was killed by this disease.

Since 1925, some tung trees in the southern United States are known to have been attacked by the fungus *Cercospora aleuritidis*. This fungus caused angular, dark-colored leaf spots, which apparently did

little or no damage. However, about 1953, premature defoliation of trees in large blocks of orchard occurred in August or early September. Early defoliation cannot fail to weaken the trees and reduce their productive capacity. It is not known whether the fungus suddenly became more virulent, or if the weather was especially favorable for its development. Control measures, including breeding resistant varieties, are being studied.

Tung is also subject to a bacterial leaf spot (caused by *Pseudomonas aleuritidis*), to a disease known as alcoholic flux, and to a disease known as web blight (caused by the fungus *Corticium microsclerotia*) that sometimes attacks young trees in the nursery. None of these diseases is common or likely to cause serious loss.

HARVESTING

Tung fruits mature and drop to the ground in late September to early November. At the time the fruits fall, they contain as much as 60 percent moisture by weight. They should be left on the ground 3 or 4 weeks until the hulls are dead and dry and the moisture content of the whole fruit has dropped to about 30 percent. The fruits do not deteriorate on the ground until germination starts in the spring, but if they are gathered before the leaves fall, a great deal of expense and trouble is saved.

The fruits are nearly always gathered by hand into baskets or buckets. Various types or receptacles may be used, although openwork-wire bushel baskets are favored. The price per bushel given pickers is adjusted according to conditions in the orchard. In an orchard free from grass, weeds, and briars, where the trees are producing from 1½ to 2 tons per acre, an average picker can gather 60 to 80 bushels per day. On the other hand, if the orchard is bearing only one-half ton to the acre and the fruit is hidden among weeds and briars, a picker will find it difficult to gather 30 to 40 bushels per day.

To encourage workers to gather fruit all through the season, many growers have the crop gathered from the poorer sections of their orchards first. The pickers generally work in crews of 15 to 20, with a foreman for each crew.

The harvest usually has to begin before the last fruits have fallen. It is difficult if not impossible to shake all the remaining fruits off the trees so that harvesting can be completed with one gathering. Long, tough stalks or stems permit the tung fruits to swing rather than to jar loose; therefore, it is almost always necessary to make a second picking, or "scrapping." The rate paid for scrapping is generally two or three times more than for the first picking. Foremen may find that some workers are inclined to leave a good deal of fruit under the trees during the first harvest so that they may earn more during the scrapping operation.

As gathered from the ground, tung fruit is seldom dry enough for delivery to the mill. It is usually sacked, placed in trees, and allowed to dry for 2 or 3 weeks.

However, most mills are equipped with driers that make possible the processing of whole fruit that has 30 to 40 percent moisture content. The kernels of these fruits contain only about 15 to 20 percent moisture because they absorb moisture to a much less extent than the shells and hulls. Therefore the grower may feel that it would be advantageous to deliver the crop to the mill as soon as the fruits are gathered.

Wet fruit will contain a low percentage of oil. If the grower is to

be paid on the basis of oil delivered and the fruit is delivered wet, the grower will receive less per ton than he would if it were dry. Also, if wet fruit is milled for the grower's account, he will have to pay for milling a larger number of tons than he would if dry fruit were delivered.

The changes in weight and in percentage of oil content when any given lot of tung fruit gains or loses moisture are of vital importance to tung growers because they affect the cost (and sometimes the guaranteed recovery of oil) in custom milling.

Growers may sometimes wish to equate the oil content of different lots of fruit to a common moisture basis; for example, 15 percent. The rule is simple: Multiply the reported oil content percentage by 85 and divide by 100 minus the reported moisture percentage. Thus, if 16.2 percent oil is reported at 24.6 percent moisture, the calculations are:

$$\frac{16.2\times85}{100-24.6}=\frac{1377}{75.4}=18.3$$

If the grower decides to dry the fruit before delivery to the mill, or if the mill cannot accept delivery as fast as the crop is harvested, the most common practice is to empty the baskets into crocus (burlap) sacks and hang them in the trees (fig. 21). Fruit handled in this

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FIGURE 21.—To reduce the moisture content, newly gathered tung fruits are usually sacked, placed in the trees, and allowed to dry for 2 or 3 weeks.

manner does not heat or spoil even during a long period of rainy winter weather. However, both sacks and labor are expensive. For an average crew of 15 to 20 pickers, 3 men are required to fill the sacks, tie or sew them, and put them in the trees. After 2 or 3 weeks of dry weather, the sacks are removed and "ramped out;" that is, loaded on wagons or tractor-drawn trailers and carried to a main road where they are stacked for pickup and transport by trucks to the mill.

Instead of hanging sacks of tung fruit in the trees to dry, many growers place the fruit in field storage sheds. A disadvantage of such storage is that deep layers of fruit dry slowly, and when the fruit has a moisture content of 25 percent or more, it is likely to heat and spoil.

Growers who wish to store the fruit in sheds have the pickers dump their baskets into tractor-drawn trailers. The pickers are credited with each basket delivered. The tractors then haul the trailers to the storage shed where the fruit is carried up in elevators and distributed by conveyors to different bins. Wet fruit must be distributed in thin layers over a number of different bins, and must have time to dry before more is added. This method requires a large storage shed with many bins, as well as good judgment and close attention to avert fruit spoilage.

Present methods of harvesting, handling, and storing the tung crop are costly and not entirely satisfactory. If improved methods can be worked out, costs may be reduced. Engineers of the Agricultural Engineering Research Division, Agricultural Research Service, U. S. Department of Agriculture, are working on the development of machines for picking up the fruits from the ground and for hulling at the orchard.

ESSENTIALS FOR PROFITABLE PRODUCTION

The average yield of tung orchards is about one-half ton of whole fruit per acre per year. Most of the present bearing tung orchards were planted before much was known about the soil requirements of the tree or its cultural needs. Also, the only planting stock available consisted of unselected seedling trees, which range widely in productivity. Some of these trees are practically barren.

Nevertheless, orchards of such seedlings, planted on good soil and adequately cared for, often yield 2 tons per acre per year over a period of years, and individual crops averaging 3 tons per acre or more have been harvested in fairly extensive orchards.

Tung growers should aim at attaining high average yields—1½ to 2 tons per acre of fruit with high oil content. Prices for oil will depend on price supports, domestic production, imports, and demand. At 20 cents per pound for oil, a grower would receive $51.10 per ton for fruit of 18.5 percent oil content delivered (86 percent recovery), after deduction of the average milling costs of $12.50 per ton. On the same basis, fruit of 22 percent oil content would return $63.10 per ton.

High average yields of fruit having a higher oil content than presently obtained may be expected from new orchards if growers will follow these recommendations: Select orchard soil carefully; plant only seedling trees of progeny-tested varieties that are best suited to the area in which they are to be grown; and give the orchard adequate culture and fertilization.

OTHER PUBLICATIONS

Listed below are other publications of the U. S. Department of Agriculture that contain helpful information regarding the tung industry, the establishment of orchards, and the care of trees. Unless otherwise indicated, these publications may be obtained free from the Office of Information, U. S. Department of Agriculture, Washington 25, D. C.

Farmers' Bulletin 1740, Vetch Culture and Uses. 1955.
Farmers' Bulletin 1946, Lupines: New Legumes for the South. 1947.
Farmers' Bulletin 1970, Conserving Soil and Moisture in Orchards and Vineyards. 1945.
Farmers' Bulletin 1980, Crotalaria Culture and Utilization. 1946.
Farmers' Bulletin 2007, Mixing Fertilizers on the Farm. 1949.
Farmers' Bulletin 1148, Cowpeas: Culture and Varieties. 1947, rev. (Available only from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., 10 cents.)
Farmer's Bulletin 1526, Clearing Land of Brush and Stumps. 1927. (Available only from the Superintendent of Documents. 20 cents.)
Leaflet 119, White Clover. 1947.
Leaflet 160, Crimson Clover. 1947.

Mimeographed Circulars, "Chemical Control of Briars, Volunteer Tung Seedlings, and Other Broad-Leaved Weeds in Tung Orchards," and "Collecting and Preparing Tung Leaf Samples for Chemical Analysis," may be obtained from U. S. Department of Agriculture Tung Laboratories at Bogalusa, La.; Cairo, Ga.; or Gainesville, Fla.

Tung Tree Foliage Poisoning of Cattle, Fla. Agr. Expt. Sta. Bul. 376, can be obtained from the Florida Agricultural Experiment Station, Gainesville, Fla.

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Washington 25, D. C. Price 20 cents